LIQUID ROBOTICS®

The Digital Ocean

How Systems Can Work Together to Solve Our Planet's Biggest Challenges

The ocean is full of answers:
insights into climate change, solutions to help us feed a growing population, and data that could foster sustainable approaches to economic growth.

New technology is making ocean data more accessible than ever. Pervasive connectivity is becoming more of a reality every day, enabled by a growing network of platforms and sensors across the ocean surface, the air above, and the vast water column below.

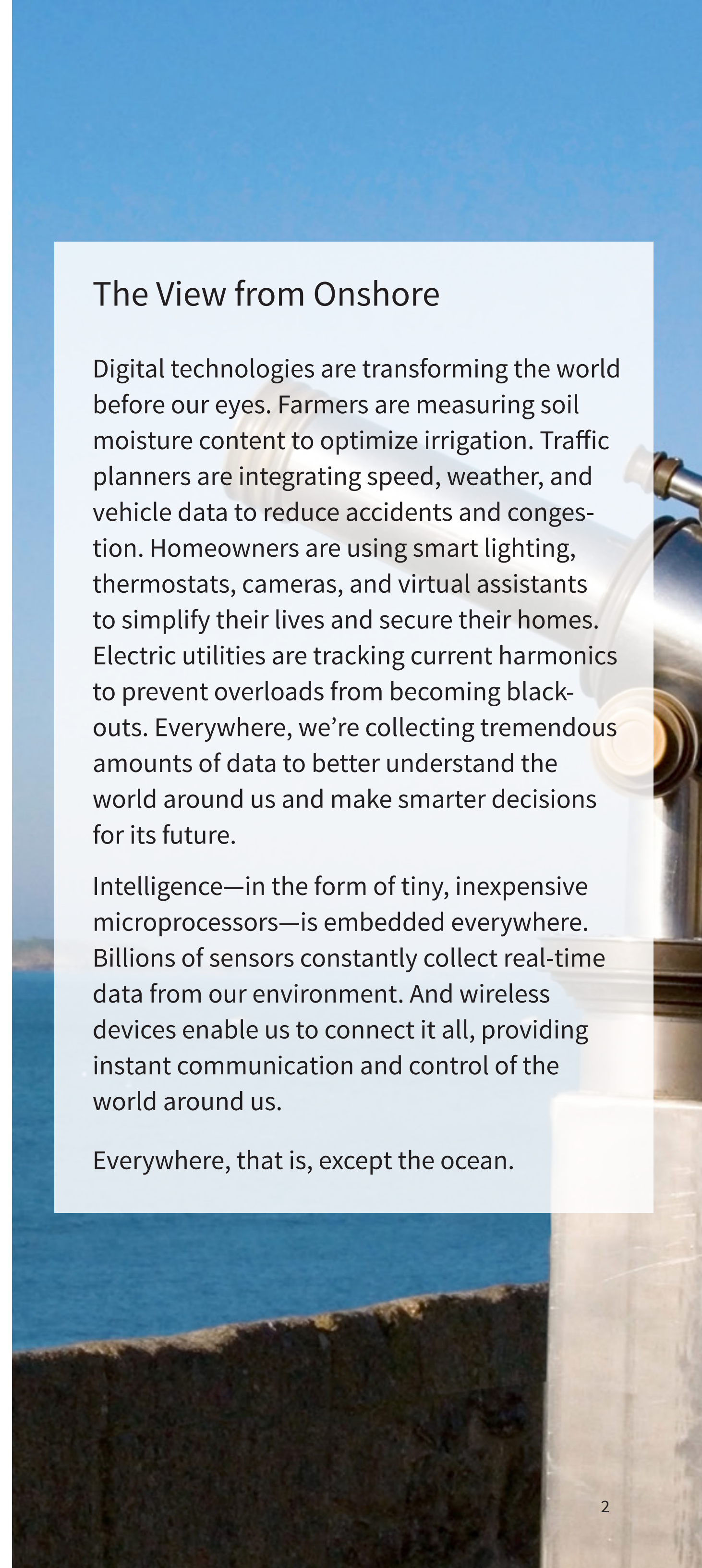
We believe this—the Digital Ocean—is essential to the future of our planet.

Introduction

The Digital Ocean is not about a single technology. It's about how multiple systems can come together to solve some of our planet's biggest challenges.

This ebook is designed to provide a basic understanding of the concepts underlying the Digital Ocean. It should enable productive discussions about technologies, policy, and practical solutions to current and future challenges. Innovators and technologists may be inspired to consider a "bigger picture" view and look toward the power of making connections and creating solutions that are greater than the sum of their parts. Problem solvers and policy makers will see that concepts based on readily available data ashore can be employed at sea, opening new approaches to important problems.

We have many of the pieces we need today, but bringing the full potential of the Digital Ocean to life requires a collective effort to build it together.



The View from Onshore

Digital technologies are transforming the world before our eyes. Farmers are measuring soil moisture content to optimize irrigation. Traffic planners are integrating speed, weather, and vehicle data to reduce accidents and congestion. Homeowners are using smart lighting, thermostats, cameras, and virtual assistants to simplify their lives and secure their homes. Electric utilities are tracking current harmonics to prevent overloads from becoming blackouts. Everywhere, we're collecting tremendous amounts of data to better understand the world around us and make smarter decisions for its future.

Intelligence—in the form of tiny, inexpensive microprocessors—is embedded everywhere. Billions of sensors constantly collect real-time data from our environment. And wireless devices enable us to connect it all, providing instant communication and control of the world around us.

Everywhere, that is, except the ocean.

Welcome to the Digital Ocean

Imagine a globally networked ocean connecting sensors, vessels, aircraft, satellites and unmanned systems. A place where data is available on demand, around the clock, and data sets are rich and robust over time and space. So that decision makers can keep pace with a constantly changing world.

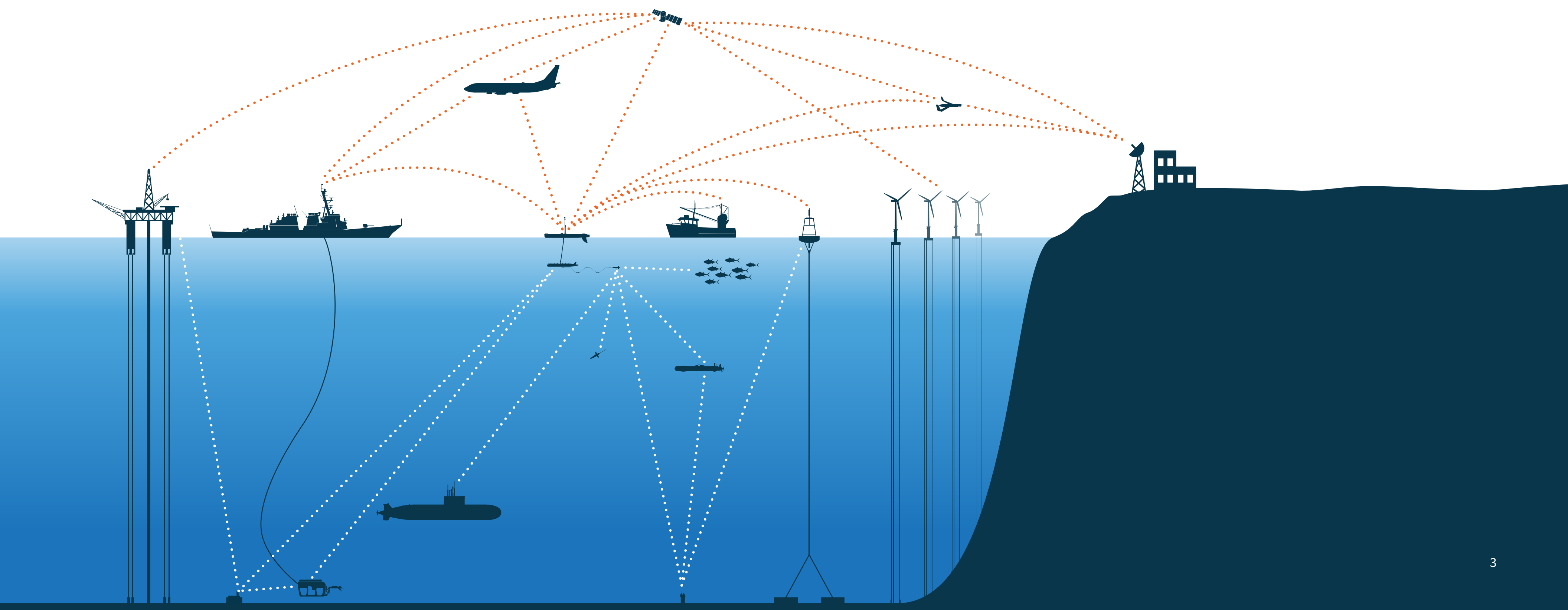
Nations could safeguard their waters from illegal fishing, smuggling, and trafficking. Businesses could uncover new energy resources, shipping routes, and economic opportunities in places where it was too costly or risky to go before. And scientists could improve existing models and develop new ones to better understand climate change and weather patterns.

This is the Digital Ocean. And it's taking shape all around us.

A System of Systems

The Digital Ocean depends on multiple systems coming together to solve some our planet's biggest challenges. Here's how we break it down:

- **Platforms**—How we put the infrastructure in place
- **Instrumentation**—How we get the data
- **Connectivity**—How we communicate the data
- **Analytics**—How we make sense of it



Platforms in the Digital Ocean

On land, governments and industry have spent decades building out the infrastructure we need to support the economy, national security and daily life, from roads and power lines to communication networks.

When we think about building out the infrastructure for the Digital Ocean, the ocean poses some unique challenges.

Energy: Success in the ocean often requires the ability to operate far from shore. Systems must be able to harvest energy from the environment, operate efficiently from battery power, or have ships available to recharge them. Today, high-power platforms like ROVs predominate, requiring costly support assets to operate and recharge them. The ongoing transition to energy-harvesting and energy-efficient unmanned vehicles promises to unlock new operational possibilities in the Digital Ocean.

Communications: Radio waves and light don't travel through the ocean like they do through the atmosphere. Which makes getting information into or out of the ocean difficult. To solve this challenge, operators either use cables to deliver information and power to subsea systems, or they use gateway devices on the surface to communicate between subsea and aerial/space systems.

Positioning: The ocean is an incredibly large operating environment where strong currents, wind, and waves make it challenging for even moored systems to stay in one place. Today, positioning infrastructure for devices on the surface is provided by satellites. Underwater, acoustic positioning systems help underwater vehicles, submarines, and other subsea systems within their range accurately navigate the ocean environment.

The Digital Ocean depends on multiple platforms to provide this infrastructure: aerial vehicles and satellites above, buoys and vehicles on the surface, and underwater vehicles and seafloor systems below.

In the Sky

Satellites deliver critical spatial positioning information to help ships and autonomous systems navigate. They also enable communications, transporting information from the surface to shore, and back again. However, satellite transmission is costly, so designers of data collection systems must carefully think about what and how much data they can afford to send.

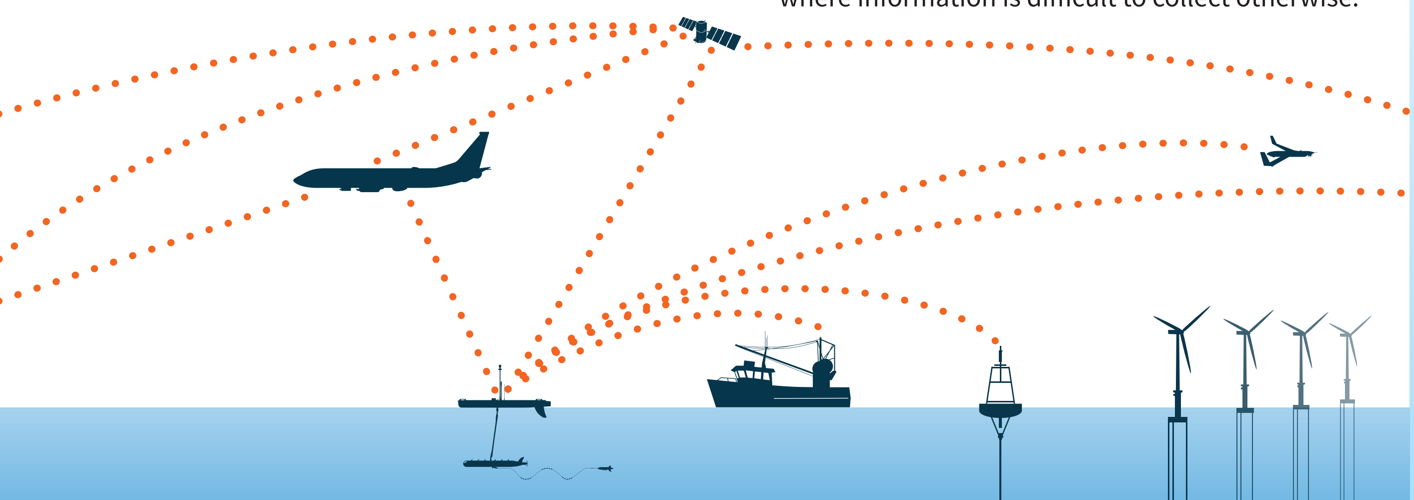
Unmanned aerial vehicles (UAVs) are increasingly playing a role. Often equipped with high-definition imaging, thermal or infrared cameras, and other sensing technologies, UAVs can acquire higher resolution data than is possible with satellites, and offer more control over placement.

At the Surface

The Digital Ocean cannot exist without a persistent, surface presence connecting the subsea environment with the world ashore. Systems such as buoys and unmanned surface vehicles (USVs) are inherently less expensive than manned platforms and ships, and offer greater persistence and coverage.

Buoys are best used for stationary installations closer to shore, since the cost and complexity of deploying and maintaining them rises dramatically the farther from port they are.

Unmanned surface vehicles have the mobility that enables them to inexpensively drive themselves to remote locations, operating far from logistical hubs where information is difficult to collect otherwise.



The Wave Glider® Platform

The Wave Glider plays a fundamental role in the Digital Ocean. Operating at the surface, it provides an essential gateway between the seafloor and space. Integrated positioning enables it to hold station like a buoy or autonomously navigate challenging sea states, collecting data and sending it in real time to the decision makers who need it. And since it's able to harvest energy from the ocean and sun, it's able to be at work for many months, even up to a year at a time.

Underwater

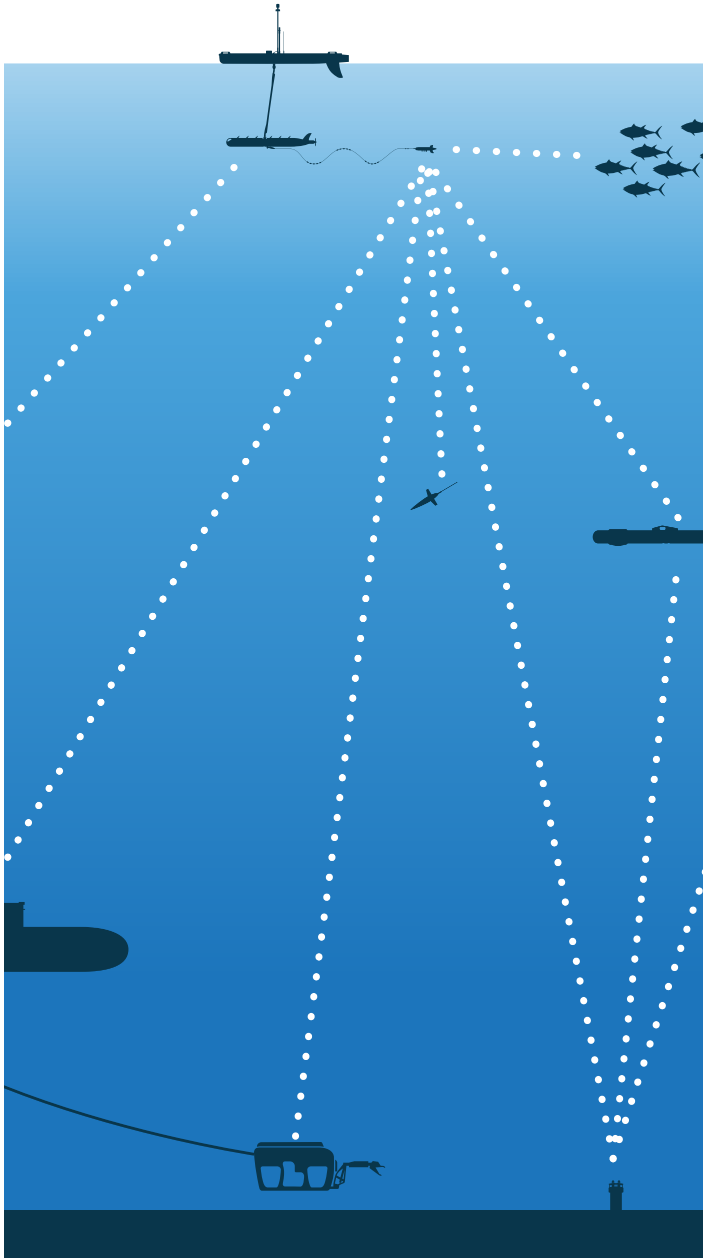
Autonomous underwater vehicles (AUVs) are battery-powered systems that offer greater mission flexibility than remotely operated underwater vehicles (ROVs), which require a surface vehicle for control and power. Traditionally, battery life has limited the types of tasks AUVs can perform in the ocean; however, advances in battery and power management technologies continue to extend their range and capabilities.

Gliders using buoyancy-based propulsion offer strong range and duration for underwater ocean sampling, allowing for missions of up to weeks or months while surfacing at regular intervals to transmit their data to shore.

On the Seafloor

Seafloor networks have conventionally relied on cables for communication and power. Today, we're beginning to see more battery-powered nodes that rely on acoustic communications. These systems bring a number of advantages, since they eliminate the expense of cabling and can be positioned where they are needed.

Each platform performs a solid role on its own, but powerful opportunities emerge when we bring them together to form systems capable of even more.



Instrumentation in the Digital Ocean

Sensors are rapidly evolving to meet the demands of the autonomous systems market. They're getting smaller, smarter, lighter, and more energy efficient. They are also integrating more intelligence to enable autonomous operation.

The miniaturization and power reduction of sensors means that more of them can be deployed. Multi-sensor systems enable users to maximize the value of missions by combining a variety of capabilities from maritime surveillance to metocean data collection and communication.

From meteorological and oceanographic sensors, to biological and chemical sensors, to cameras and acoustic sensors, there is virtually no limit to what we can measure.

The question then becomes: How can we deploy and link sensors and the data they produce in new ways to solve problems?

Sensor Fusion in Action

Onboard processing of data from multiple sensors can be used to greatly reduce data transmission costs and improve decision making. The United Kingdom's Foreign & Commonwealth Office recently used this capability to cost-effectively police illegal fishing in the Pitcairn Islands Marine Reserve.

Combining inputs from image, acoustic, and AIS sensors, the Wave Glider demonstrated it could detect suspect vessels using underwater acoustics, visually inspect with onboard camera, and then send back contact reports and images of these vessels to authorities. This type of intelligence across sensors is critical for reducing data overhead and extending mission capabilities.

Connectivity in the Digital Ocean

We take ubiquitous connectivity for granted on land. Today, consumers can manage their homes from thousands of miles away. Farmers can know when to water their crops and activate irrigation systems without ever stepping into the field. And businesses can spot and capitalize on opportunities as quickly as they appear.

Likewise, in the Digital Ocean pervasive connectivity will give us instant access to the information we need to manage our most valuable resources, drive economic growth, and protect our cities and nations. But, first, we need to overcome the unique communications challenges presented by the ocean.

Underwater Communications

The things we rely on for communication in our day-to-day lives—like cellular networks and Bluetooth—don’t work well underwater. In the air, we can stream high-definition video fairly easily; underwater we’re working with text-message-level communications at best.

Because of these limitations, subsea systems have to be a lot smarter about what data they choose to send. Ample on-board data processing and compression are needed in each network node to reduce the size of data packets.

Historically, ships have provided the primary data collection point for underwater systems, but their high operational cost means they are not a realistic option for persistent, wide-scale deployments. In response, smart buoys and unmanned surface vehicles have emerged, enabling low-cost, persistent communications gateways between subsea systems and satellites and aerial assets above.

Recent innovations in underwater optical communications are also helping to solve this challenge, offering the potential to provide data transmission rates that are higher than acoustic rates by orders of magnitude.

Analytics in the Digital Ocean

On land, we're able to collect data from billions of sensors and send it to the cloud to process and analyze it. Ocean instruments, however, do not have the luxury of high-bandwidth communications to on-shore compute resources.

So we have to be a lot smarter about how we handle data. Nodes need greater levels of intelligence to determine if what they see, hear, or sense is worth sending back. Many subsea systems now include basic analytical functions. Likewise, unmanned and manned underwater platforms continue to add higher levels of processing power to enable local data analysis and more autonomous operation when network connectivity is low or unavailable.

Finding Answers in a Sea of Data

Often, making sense of the information in front of us starts with understanding what happened in the past. We need a baseline of historical information about activities or patterns over longer durations to better understand the changes happening around us or what might happen in the future. Mining this data can help us understand things like which areas of the ocean are likely hot spots for illegal fishing, whether hydrocarbon concentrations are elevated because of an oil spill or natural seep, and how the location of a wind farm might affect marine life.

A Glimpse of What's to Come

Big data in the ocean is still in its early stages. But there are exciting developments underway from private enterprises, nonprofits, and governments. Some examples:

- Aggregating data to improve weather forecasts and climate data sets
- Using open-source satellite data to detect illegal fishing
- Integrating oceanographic and scientific data sets to improve policymaking and foster more sustainable industry development

How Will You Be a Part of the Digital Ocean?

With the Digital Ocean, we can crack down on illegal fishing, smuggling and trafficking. Instantly detect undersea threats. And create a sustainable food supply to feed our growing billions.

The Digital Ocean is bigger than one product or company. It's a massive vision for what's possible when the world's best minds unite behind a shared purpose. Realizing this vision will require collaboration between system vendors and forward-thinking leaders from every field.

Around the world, we have begun to see leaders step forward to deploy new solutions to some of the big challenges we face. Today, you'll find them in Japan providing advanced warning of tsunamis. You'll find them along the eastern seaboard tracking threatened fish populations. You'll find them in the Gulf of Mexico providing a cost-effective and safe solution for locating and extracting oil. And sometimes, you won't find them at all, because they're silently patrolling our coastlines, so our nations can rest easily at night.

From platforms and instrumentation, to connectivity and analytics, we have many of the pieces today. Now we need to come together to help shape the future of our planet and the ocean.

We hope you'll join us.

www.liquid-robotics.com/DigitalOcean

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